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# EFFECTS OF GROUNDWATER PUMPING IN THE LOWER APALACHICOLA–CHATTAHOOCHEE–FLINT RIVER BASIN

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ABSTRACT: A groundwater-flow model developed by the U.S. Geological Survey was used to evaluate the effects of agricultural groundwater pumping on the groundwater-flow system of the Upper Floridan aquifer in the lower Apalachicola–Chattahoochee–Flint River basin in southwest Georgia and adjacent parts of Alabama and Florida. To quantify the relative effects of groundwater pumping at different locations within the model area, pumping was applied at numerous locations in successive simulations. By comparing each result to a base simulation, changes in groundwater flow at model boundaries—streams, lakes, and regional model boundaries—were computed and stored in a response matrix for each location. Queries to the response matrix were designed to determine the sensitivity of various boundary flows to agricultural pumping. Contour plots of results illustrate the spatial variation of the sensitivity to pumping across the model area.

## INTRODUCTION

Competing demands for water in the Apalachicola–Chattahoochee–Flint River basin (ACF) have created a decades-long dispute between the States of Alabama, Florida, and Georgia and the U.S. Army Corps of Engineers (USACE), who manages the releases of water from large federally constructed reservoirs in the basin. Lake Lanier, the uppermost of the reservoirs on the Chattahoochee River is a principal water supply for metro Atlanta. Agricultural groundwater pumping in the lower part of the basin has lowered water levels in the Upper Floridan aquifer sufficiently to reduce groundwater flow (baseflow) to the three rivers and their tributaries, and deplete water stored in the aquifer in adjacent river basins to the southeast. Minimum flows in the Apalachicola River at Chattahoochee, Florida, below Lake Seminole, the most downstream of the reservoirs, are maintained by the USACE to protect the aquatic habitat of threatened and endangered species (Gulf sturgeon and several mussel species). Oyster and blue crab fisheries in Apalachicola Bay depend on nutrients in and sufficient flow of freshwater from the Apalachicola River. Recent droughts have intensified water-supply issues, and the extreme drought of 2011 brought most streams in the lower ACF to period-of-record low flow, with many smaller streams drying out for weeks on end.

A response matrix created from a groundwater-flow model provides a means to determine the effects of agricultural groundwater pumping in the lower ACF on hydrologic boundary flows of primary concern to water managers. For example, queries to a response matrix could identify areas within the model region where pumping affects (1) groundwater discharge to surface water in the regional model area, (2) groundwater discharge to targeted streams as compared to low-flow statistics at specific streamgaging stations, and (3) regional flow across lateral model boundaries and regional drainage divides. Results would enable water managers to assess the impact of agricultural pumping and drought on the groundwater-flow system and baseflow to streams and to develop mitigation strategies to conserve water resources and preserve aquatic habitat.

## METHODS

In 2006, the U.S. Geological Survey, in cooperation with the Georgia Environmental Protection Division, developed a finite-element groundwater-flow model of the Upper Floridan aquifer in the lower ACF in southwestern Georgia and adjacent parts of Alabama and Georgia (Jones and Torak, 2006). The model simulated irrigation pumping during a drought year (2001) and quantified pumping effects on groundwater levels and aquifer-stream flow through water-budget calculations for the groundwater system. Aquifer-stream flow is the sum of groundwater outflow to and inflow from streams, and is an important consideration for water managers in the development of water-allocation and operating plans. Argus ONE™ (use of product names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government), a software package that combines a geographic information system (GIS) and numerical modeling in an Open Numerical Environment, facilitated the design of a detailed finite-element mesh to represent the complex geometry of the stream system in the lower basin as a model flow boundary. A withdrawal rate of 0.58 cubic foot per second ($ft^3/s$)—equivalent to a typical center-pivot system irrigating a 200-acre field to a depth of 2 inches per month—was applied in repeated steady-state simulations at each of the 18,951 model nodes. Comparison of nodal simulation results with a base case, representing drought conditions during October 1999 and no agricultural withdrawal, quantified changes in aquifer-stream flow, aquifer-lake flow, and regional-boundary flow. The changes, or responses, were stored in a response matrix for each node. Argus ONE™ enabled generation of shaded contour plots of results of response-matrix queries.

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## RESULTS

Streamflow reduction due to irrigation pumping is a management concern as it affects the minimum flow in the Apalachicola River at Chattahoochee, Florida, located at the Georgia-Florida state line near the downstream model boundary. To determine the relative effects of pumping throughout the model area on streamflow at that location, the response matrix was queried for the total change in aquifer-stream and aquifer-lake flow that resulted from pumping each node. Nodal results were represented as a percent of the applied pumping rate (0.58 $ft^3/s$), and are depicted on a shaded-contour map (fig. 1). Generally, the closer the node is to the stream, the greater the effect on streamflow. For example, the dark red-shaded areas indicate a reduction in aquifer-stream or aquifer-lake flow equivalent to 90-100 percent of the nodal groundwater pumping rate. The remaining 0-10 percent equivalent of the pumped groundwater is from change in regional flow or leakage from the overlying overburden. Conversely, the dark blue-shaded areas represent reduction in aquifer-stream or aquifer-lake flow equivalent to less than 10 percent of the groundwater pumping rate. During the 2001 drought, the peak monthly agricultural irrigation rate in the middle of the growing season was about 2 inches per acre. Applying that peak rate to all the groundwater irrigation systems that were in the lower ACF at that time, the response matrix allows calculation of the total reduction in aquifer-stream and aquifer-lake flow to upstream streams and lakes (shown in white in fig. 1) due to peak monthly groundwater withdrawal of about 1,180 $ft^3/s$. Resulting streamflow reduction in the Apalachicola River at Chattahoochee, Florida was about 540 $ft^3/s$, or about 46 percent of total groundwater withdrawal.

Results in figure 1 consider only the overall reduction in streamflow near the downstream model boundary, but do not consider the relative size of individual rivers and tributary streams affected by irrigation pumpage, and do not address the issue of smaller streams, which support endangered aquatic species, going dry. For example, an aquifer-stream flow reduction that would be significant to a smaller stream like Spring Creek, which has often gone dry in recent years, may scarcely diminish a large stream like the Flint River. Carter and Putnam (1978) published low-flow statistics for gaging stations in Georgia, including Flint River at Bainbridge, Georgia, and Spring Creek near Iron City, Georgia, for periods of record before 1974, prior to the advent of large-scale agricultural irrigation in the lower ACF. To consider the relative effects on these two streams of contrasting magnitudes of flow, a query of the response matrix was used to evaluate how aquifer-stream flow reductions compare with pre-irrigation 7Q10 low streamflow—a statistical low flow that would occur during 7 consecutive days, on average, once every 10 years—commonly used as indicative of drought conditions. Pre-irrigation 7Q10 low flows were 2,300 $ft^3/s$ and 18 $ft^3/s$, respectively, for the Flint River at Bainbridge, Georgia, and the Spring Creek at Iron City, Georgia, gages. The response matrix yielded reductions in aquifer-stream and aquifer-lake flow for stream reaches upstream of each of these gages, and the result at each node was determined as a percent of the 7Q10 low flow of each gage. At the Flint River gage, streamflow reduction caused by pumping 0.58 $ft^3/s$ is less than 0.005 percent of the 7Q10 low flow (fig. 2, upstream streams and lakes shown in white); whereas, at the Spring Creek gage the same pumping rate reduces streamflow up to 1 percent of the 7Q10 low flow (fig. 3, upstream streams shown in white). Simulated pumping for an irrigated depth of 2 inches at all the 2001 irrigated acres (1,180 $ft^3/s$), reduced flow in the Flint River at Bainbridge, Georgia, by about 340 $ft^3/s$ (about 15 percent of the 7Q10 low flow), and reduced flow in Spring Creek near Iron City, Georgia, by about 25 $ft^3/s$ (about 140 percent of the 7Q10 low flow). Streamflow reductions larger than 100 percent of the 7Q10 low flow could cause dry stream conditions.

The general effect of groundwater pumping on groundwater flow across the eastern and southeastern regional boundary of the model, where groundwater levels have been in steady decline for decades, was assessed by querying the response matrix for change in regional-boundary flow expressed as a percent of the applied pumping rate (fig. 4), similar to figure 1. A large dark red-shaded area in the extreme easternmost part of the model area indicates increased groundwater flow across the regional boundary equivalent 90-100 percent of the groundwater pumping rate of 0.58 $ft^3/s$. Simulated pumping for an irrigated depth of 2 inches at all the 2001 irrigated acres (1,180 $ft^3/s$) causes about 145 $ft^3/s$ of groundwater to flow into the model area across the eastern regional model boundary (shown as blue line). The result in figure 4 is less certain than results in figures 1–3 due to complexities and potential inaccuracies in estimating aquifer depletion and boundary flows at an artificial model boundary. Thus, figure 4 is only a generalized depiction of the simulated effects of agricultural pumping on regional-boundary flow, and may be subject to change if groundwater levels in the area of the boundary change in the future.

## REFERENCES

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Jones, L.E., and Torak, L.J., 2006. Simulated Effects of Seasonal Ground-Water Pumpage for Irrigation on Hydrologic Conditions in the Lower Apalachicola–Chattahoochee–Flint River Basin, Southwestern Georgia and Parts of Alabama and Florida, 1999–2002. U.S. Geological Survey Scientific Investigations Report 2006-5234, 83 p.

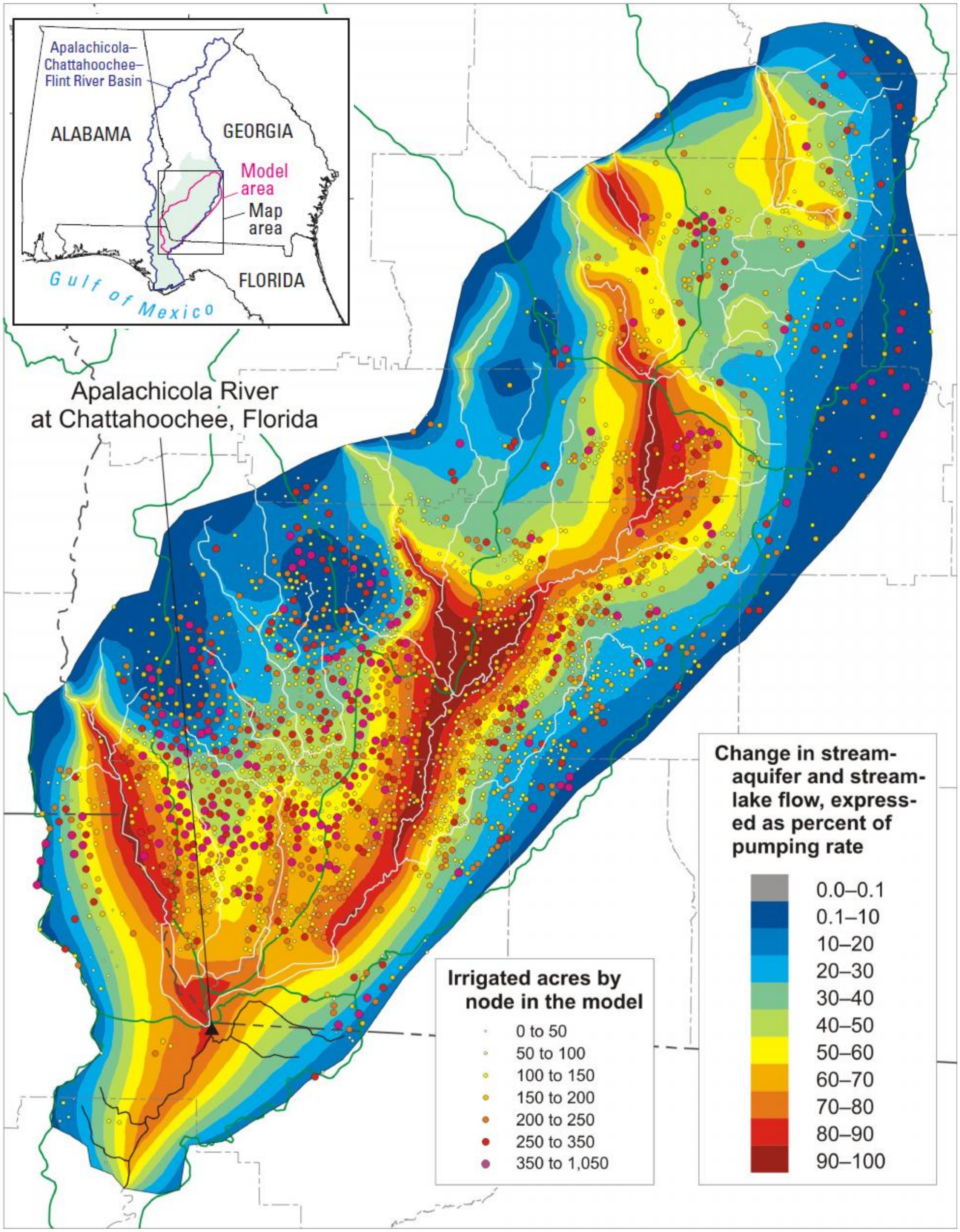


**Figure 1**. Distribution of effect of groundwater pumping on stream-aquifer and stream-lake flow throughout the entire model area, expressed as a percent of applied pumping rate.

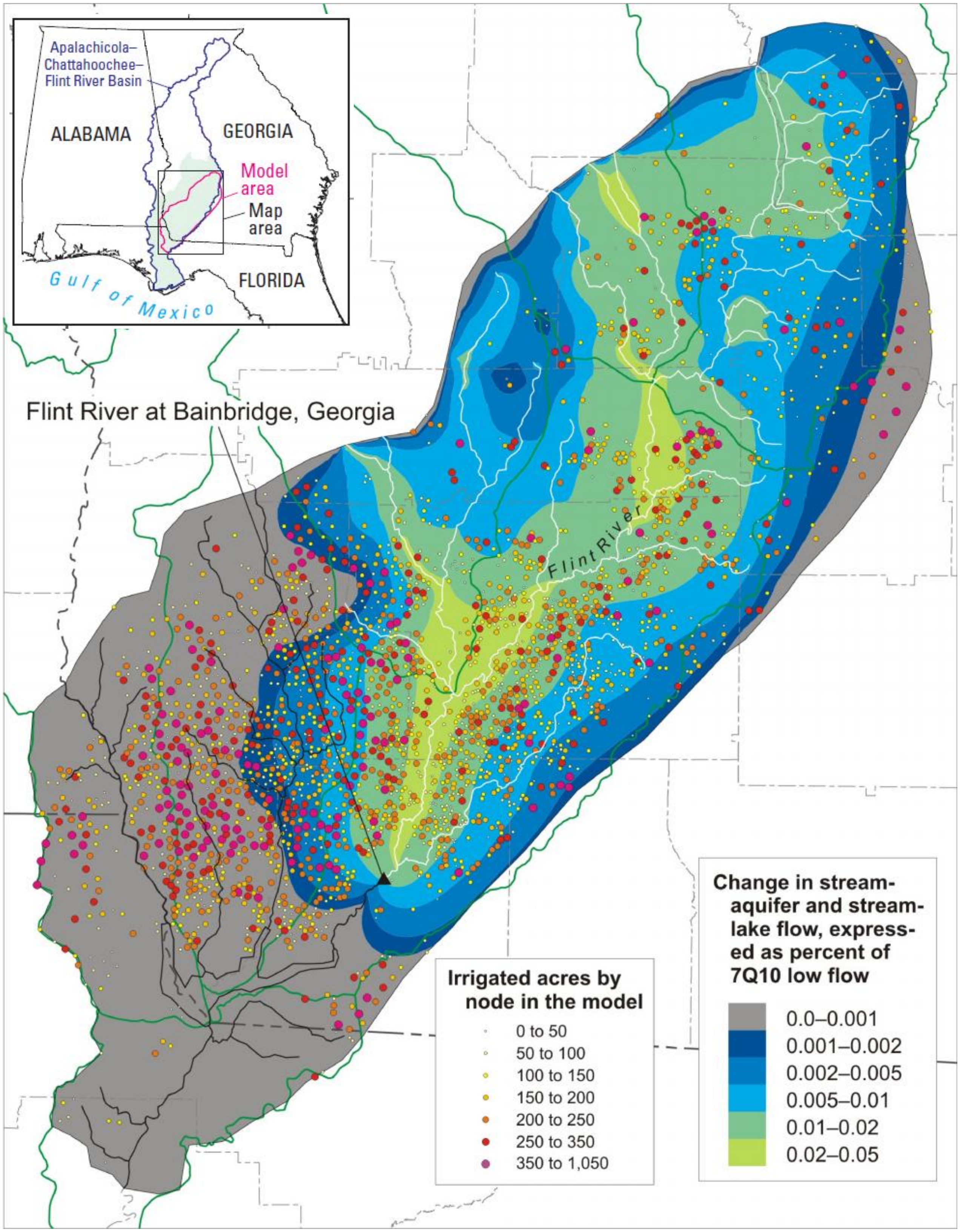


**Figure 2.** Distribution of effect of groundwater pumping on stream-aquifer and stream-lake flow upstream of the Flint River at Bainbridge, Georgia, streamgage, expressed as percent of 7Q10 low flow.

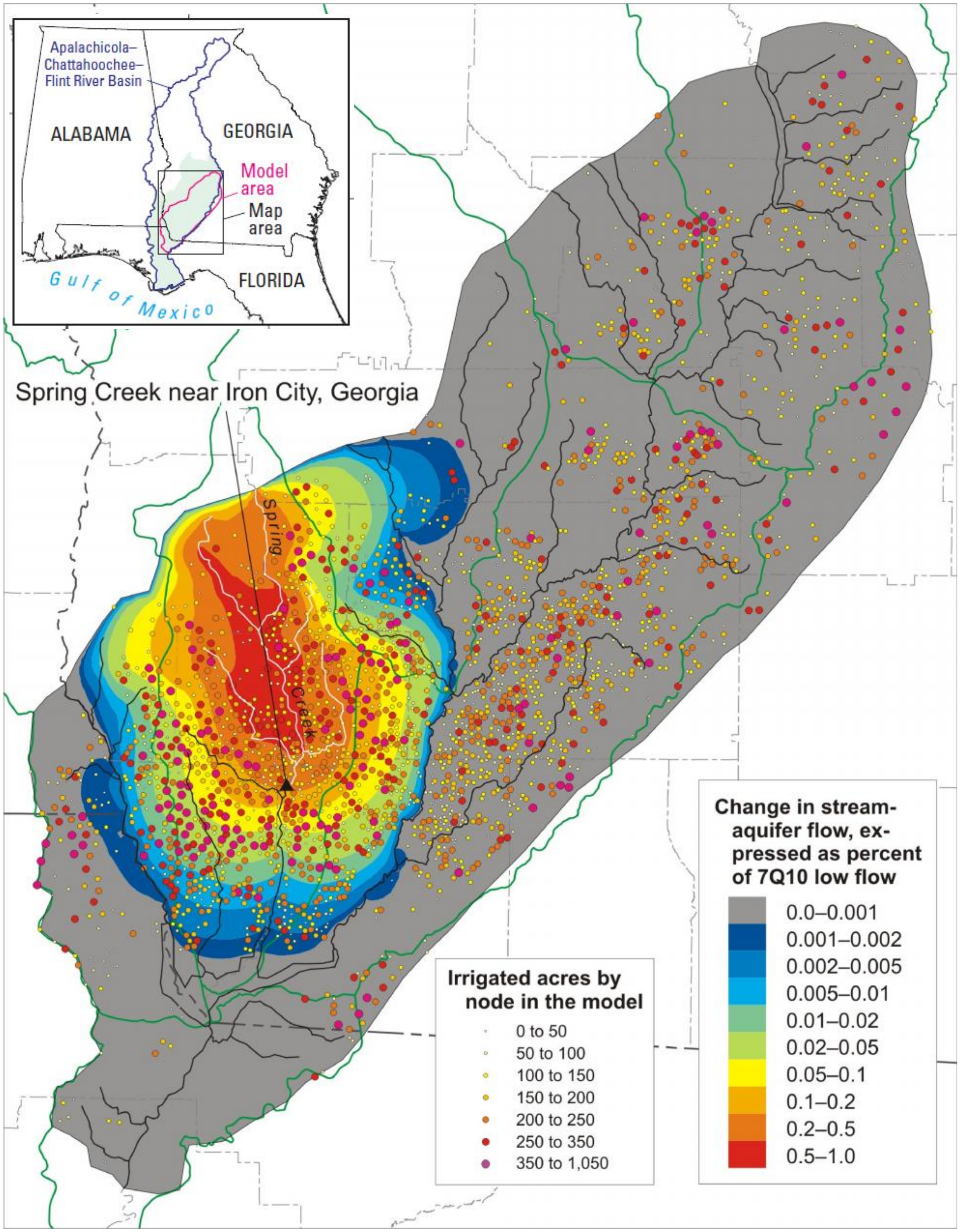


**Figure 3**. Distribution of effect of groundwater pumping on stream-aquifer flow upstream of the Spring Creek near Iron City, Georgia, streamgage, expressed as percent of 7Q10 low flow.

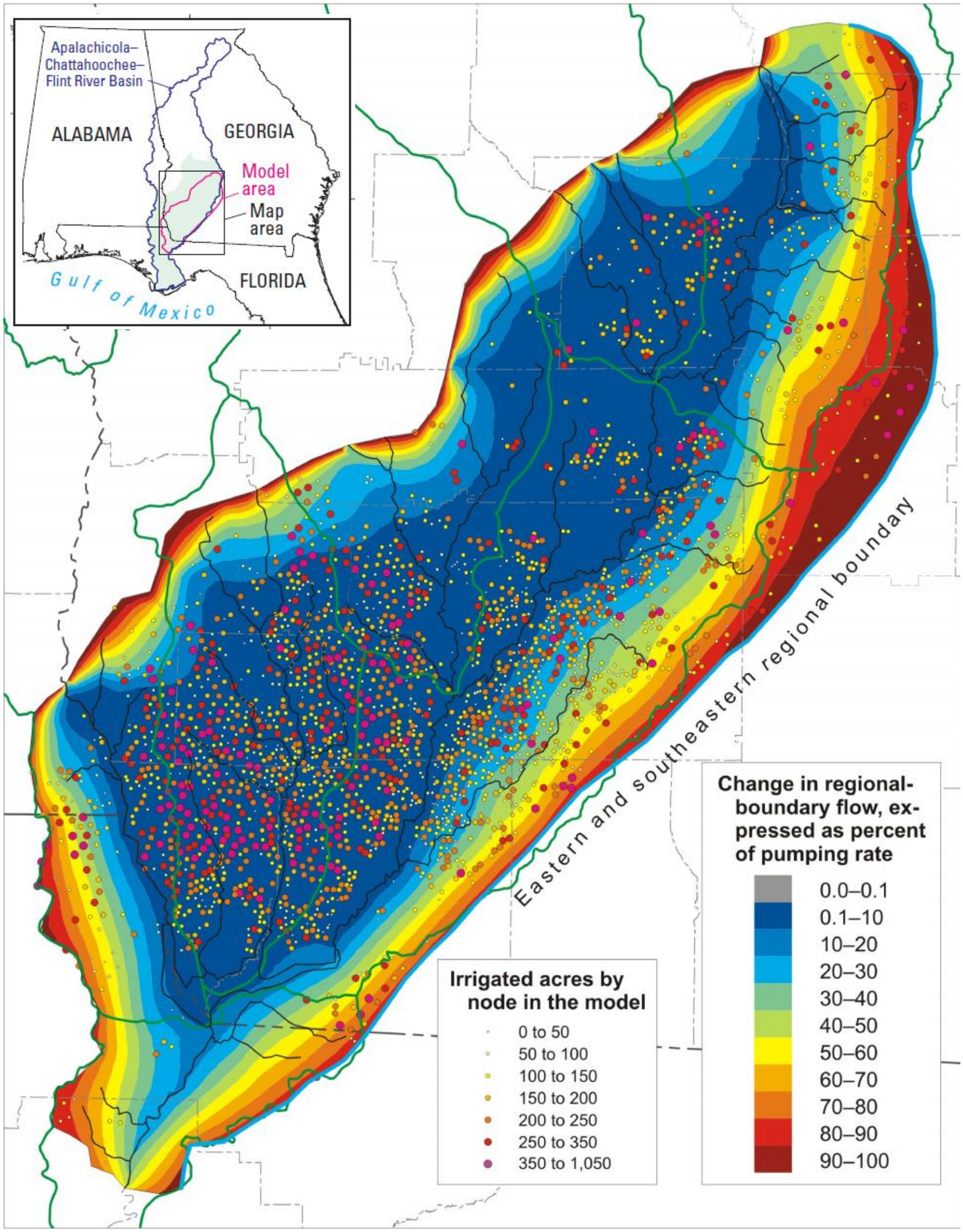


**Figure 4**. Distribution of effect of groundwater pumping on regional-boundary flow throughout the entire model area, expressed as a percent of applied pumping rate.